Final Report

"The Pixon Method for Data Compression, Image Classification, and Image Reconstruction"

Grant Number: **NAG5-9506**

Period of Performance: **5/1/00 - 4/30/02**

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June 2002

Background

As initially proposed, this program had three goals: (1) continue to develop the highly successful Pixon method for image reconstruction and support other scientist in implementing this technique for their applications, (2) develop image compression techniques based on the Pixon method, and (3) develop artificial intelligence algorithms for image classification based on the Pixon approach for simplifying neural networks. Subsequent to proposal review the scope of the program was greatly reduced and it was decided to investigate the ability of the Pixon method to provide superior restorations of images compressed with standard image compression schemes, specifically JPEG-compressed images.

Goals

The Pixon method's powerful application of the principle of minimum complexity offered great promise for high performance restoration of conventionally compressed JPEG images. As has been demonstrated in Pixon image reconstruction, the Pixon method is capable of correctly deducing the properties of structure finer than the diffraction limit. This essentially means the Pixon method correctly reproduces spatial Fourier frequencies that are not present in the data. It is capable of reproducing these features because a minimum complexity model that correctly matches the spatial frequencies that are present in the data also contains many of the spatial frequencies that are beyond the spectral cutoff of the data. Similarly, the Pixon method should be able to deduce correct features that have not been recorded in JPEG compressed images. The goal of this program was to develop Pixon software to demonstrate this capability in a practical manner.

Results

Unfortunately the results of this program have been somewhat disappointing. A number of obstacles have been identified that hinder a simple modification of the Pixon code developed for image reconstruction into an effective, computationally fast scheme for high performance JPEG decompression.

The current Pixon code is broken into 2 major pieces. The first portion of the code performs a fit to the data give a Pixon map[1]. This is the pseudoimage calculation. The second portion of the code calculates a Pixon map given the current image that has been fit to the data. For JPEG decompression, the pseudoimage calculation carries over fine from the image reconstruction code. The difficulty lies in the Pixon map calculation. The first obstacle is the non-local nature of the JPEG data. The JPEG data is an 8x8 pixel block, quantized cosine transform of the original image. Each element of a cosine transform mixes image properties from all parts of the image. For efficiency, our Pixon map calculator for the image reconstruction problem makes strong use of the assumption that all information on the image is stored locally in the data. This assumption is strongly violated here since cosine transforms store image information for a given section of the information globally, i.e., in every cosine transform coefficient.

The second obstacle makes the problem even worse for a practical computational approach for Pixon decompression. This is the fact that JPEG images employ 8x8 pixel blocks. This means that edge effects are very strong, i.e., the way a pixel in the center of an 8x8 block stores image content is quite different that how a pixel near the edge of a block stores information. This is part and parcel of block artifacts seen in high-compression JPEG images.

These effects were not unanticipated at the start of our program. However, we could not know the difficulty that would be encountered in trying to overcome these problems. A brute force procedure for Pixon decompression can, of course, be developed. However given the current computational power of desk top computers such a scheme would be only of academic interest and would not provide a useful tool for day-to-day image decompression applications. Consequently we spent our efforts at attempting to find a work-around of these fundamental problems. Unfortunately, a practical work-around to the first problem was hindered by the second problem, and given our limited resources we were unable to find a successful resolution of these difficulties during our program.

[1] The Pixon map is essentially a detailed description of the structural scale of the image at each location. To be more specific, the Pixon image (i.e., the result of a Pixon deconvolution) is a pseudoimage convolved at each location with a smoothing function with a width specified by the Pixon map.